DOCUMENT RESUME

ED 259 908 SE 045 879

AUTHOR	Albrecht, Andreas; And Others
TITLE	Your Career and Nuclear Weapons: A Guide for Young Scientists and Engineers.
INSTITUTION	California Univ., Santa Barbara. Inst. for Theoretical Physics.
PUB DATE	Jan 85
NOTE	34p.; Prepared by the Santa Barbara Study Group.
AVAILABLE FROM	Peace Resource Center of Santa Barbara, 331 North Milpas #F, Santa Barbara, CA 93103 ($2.00 each).
PUB TYPE	Reports - Descriptive (141)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Career Choice; *College Science; *Engineering; Engineering Education; Federal Programs; Government Role; Higher Education; *Industry; Nuclear Physics; *Nuclear Technology; *Nuclear Warfare; Research and Development; Science Careers; Science Education; *Sciences; Universities
IDENTIFIERS	*Nuclear Weapons

ABSTRACT

This four-part booklet examines various issues related to nuclear weapons and how they will affect an individual working as a scientist or engineer. It provides information about the history of nuclear weapons, about the weapons industry which produces them, and about new weapons programs. Issues are raised so that new or future graduates may make their own decisions about how their skills are used in science and engineering. The first part provides introductory comments. The second part provides a brief history of the arms race, listing arms control treaties. The third part examines military programs in industry and the university. A geographic chart showing the military-industrial complex in the United States is included (with regional statistics for top defense contractors, dollar awards, weapon systems produced, numbers of defense-related jobs, and members of Congressional armed services committees). Also included is a list of universities receiving top Department of Defense contracts. The fourth part examines future developments, going from MX to "star wars." Lists of suggested readings and organizations which help find non-military science/engineering employment are included in appendices. (DH)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED259908

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
✓ This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

YOUR CAREER AND NUCLEAR WEAPONS

A Guide for Young Scientists and Engineers

The Santa Barbara Study Group

SE 045 879

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Santa Barbara Study Group
Robert H. Brandenberger
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

This booklet was written by Andreas Albrecht, Robert Brandenberger, Nigel Goldenfeld, Corinne Squire and Neil Turok. We are grateful for encouragement and help in research and production to William Bialek, Carlos Frenk, Jim George, Charles Schwartz and Jim Sethna. The views expressed are not necessarily those of the Institute for Theoretical Physics.

We can be contacted at:
The Santa Barbara Study Group,
Institute for Theoretical Physics, University of California,
Santa Barbara, California 93106

Price $2.00 (includes postage and handling).
Copies may be ordered from:
Peace Resource Center of Santa Barbara,
331 North Milpas #F,
Santa Barbara, California 93103

Please make checks payable to:
Peace Resource Center/ Careers Project.

I Introduction

We all live under the threat of nuclear war. At the touch of a button the world as we know it may be destroyed. How did our perilous predicament come about?

Scientists discovered nuclear fission just before the Second World War. During the war and after, a series of political decisions were made to apply the energy and skills of hundreds of thousands of scientists and engineers to the task of designing and building nuclear weapons. These programs have steadily grown. In addition, several new weapons programs are just beginning. Present programs employ more than one in nine scientists and engineers in the United States. The programs just beginning will employ many tens of thousands more.

Do we need these new weapons? Do they make the world safer? Should you contribute your skills to their development?

This booklet is intended to be an introduction to these issues and how they will affect you as a working scientist or engineer. It provides information about the history of nuclear weapons, about the weapons industry which produces them and about the new weapons programs. We hope that it helps you to clarify these issues in your own mind, and make decisions about your career at an early stage, while you still have a wide range of options available.

Nuclear Weapons Programs Today

A sizeable and growing fraction of the jobs available in physics and engineering is in nuclear weapons-related programs. We are on the verge of a dramatic increase in programs to develop new nuclear weapons systems. A large program to develop and test weapons in space is just beginning.

Most of the new weapons are qualitatively different from previous weapons. The new missiles possess accuracies enabling them to threaten hardened missile silos and

command centers. This is likely to make both the U.S. and the U.S.S.R. more edgy. With flight times of less than ten minutes for Pershing II missiles from bases in West Germany to targets inside the Soviet Union and similar times for missiles from Soviet submarines based off the U.S. coast, there is less and less time available to check whether an attack is actually taking place or to draw back from an all-out war. In addition, weapons in space would threaten the surveillance and communications satellites vital to the early warning systems both sides rely on.

Job Opportunities, Dilemmas and Responsibilities

As a graduate scientist or engineer it is likely that a good fraction of your job opportunities will lie in military projects, quite possibly in the new nuclear weapons or space weapons projects.

Anyone who has talked to people who work on nuclear weapons knows the moral dilemmas posed by such work. These weapons, if used, as they were on Hiroshima and Nagasaki, will at the very least result in deaths and unimaginable suffering for millions of innocent people. At most, they threaten the future survival of the human species.

There are different views on the responsibility of scientists for the uses to which their work is put. Edward Teller, co-inventor of the Hydrogen bomb, wrote in 1950:

> "The scientist is not responsible for the laws of nature. It is his job to find out how these laws operate. It is the scientist's job to find the ways in which these laws can serve the human will. However it is NOT the scientist's job to determine whether a hydrogen bomb should be constructed, whether it should be used, or how it should be used. This responsibility rests with the American people and with their chosen representatives." (1)

But as Solly Zuckerman, Chief Scientific Advisor to the British Ministry of Defense for six years, points out, weapons scientists are not only responsible for innovations but also for suggesting the need for those innovations. Edward Teller himself was the chief proponent of both the Hydrogen bomb and more recently the "Star Wars" space weapons program (9). Citing many cases in his own experience of weapons labs persuading politicians of the need for new programs, Zuckerman writes:

> "..it is the man in the laboratory, not the soldier or sailor or airman, who at the start proposes that for this or that reason it would be useful to improve or devise a new nuclear warhead; and if a new warhead then a new missile, a new system within which it has to fit. It is he, the technician, not the commander in the field, who starts the process of formulating the so-called military need. It is he who has succeeded over the years in equating and so confusing, nuclear destructive power with military strength, as though the former were the single sufficient condition of military success. The men in the laboratories have succeeded in creating a world with an irrational foundation, on which a new set of political realities had to be built."(3)

Working in a nuclear weapons laboratory involves you directly in the process of proposing and even lobbying for new weapons of mass destruction. You may come to find this a difficult responsibility to bear. However similar moral dilemmas will confront you as a working scientist in industry or academic life throughout your career - whether to work on military projects which have or may have applications to nuclear weapons, whether to collaborate with others working on such projects, or whether to work on other military projects which seem to you to be necessary and justifiable.

For some of you these questions will be clear and have a simple answer. However for most the implications of your own specialized work may not be clear. Military applications often seem remote when scientific research is being done. And even work initially aimed at reducing the threat of nuclear war may later have applications which increase it.

It is not the aim of this booklet to try and make decisions for you. Our aim is only to raise these issues with you and help you reach your own decisions. We make no secret of our opinion that scientists and engineers should be concerned about how their skills are used and that in the development and building of nuclear weapons they have a special responsibilty. However we have tried as far as possible to let the facts speak for themselves. We hope that scientists and engineers of all shades of political opinion will find the material here informative and useful in reaching the personal decisions they will have to make throughout their careers.

II A Brief History of the Arms Race

The first nuclear bomb was tested in New Mexico, on July 16, 1945. Three weeks later a nuclear bomb was dropped on Hiroshima.

> "Sixteen hours ago an American airplane dropped one bomb on Hiroshima, Japan, and destroyed its usefulness to the enemy. That bomb had more power than 20,000 tons of T.N.T. It had more than two thousand times the blast power of the British Grand Slam, which is the largest bomb ever yet used in the history of warfare."
>
> - President Harry S. Truman (1).

Another Japanese city, Kokura, was to be bombed three days later. It was saved by a quirk of fate. Bad weather prevented the crew from dropping the bomb there, and so they proceeded to Nagasaki (2).

In the months following the bombings, over 130,000 people died in Hiroshima (a city the size of Austin, Texas) and over 60,000 died in Nagasaki (a city the size of Boston, Massachusetts) (3). Many deaths were slow and lingering:

> "Within seven to ten days after the A-bomb explosion, people began to die in quick succession. They died of burns that covered their bodies and of acute atomic disease (radiation sickness). Innumerable people who had been burnt turned a mulberry color, like worms, and died..." (4)

The bombs had been designed and built at Los Alamos, New Mexico under the secret "Manhattan Project". The project at its peak involved 200,000 people and cost more as a percentage of the gross national product of the U.S. than the Apollo moon project (5).

Two weeks after the bombing of Nagasaki, Stalin issued the following order to Academician Kurchatov, in charge of the Soviet bomb project:

> "A simple demand of you, comrades: provide us with atomic weapons in the shortest possible time. You know that Hiroshima has shaken the world. The equilibrium has been destroyed... Provide the bomb – it will remove a great danger from us." (6)

The arms race was on.

In 1949 the Soviet Union exploded their first atomic (fission) bomb. Shortly afterwards President Truman announced his decision to proceed with development of the hydrogen (fusion) bomb - a bomb which turned out to have almost limitless explosive power (7) - and in 1952 the first such bomb was exploded on a small island in the Pacific (8). The explosive yield was 10 megatons, roughly 1,000 times larger than the Hiroshima blast. Just nine months later the Soviets exploded their first fusion bomb (9).

The first nuclear bombs could only be delivered by airplane, and in the years following World War II, both the U.S. and the USSR expanded their long range bomber forces to many hundreds. By 1960 the U.S. had about 1,700 intercontinental range jet bombers (10) whilst the U.S.S.R. had about 1,000 intermediate range and about 150 intercontinental range jet bombers (11).

From the late '50s until the present day, the nuclear arms race has been characterized by delivery systems competition. It was recognized in the '50s that missiles travelling at supersonic speeds through space were less vulnerable and faster than bombers. In 1957 the Soviet Union deployed their first regional range SS-4 missiles, successfully tested the world's first Intercontinental Ballistic Missile (ICBM), which was eventually deployed two years later, and launched their first satellite, the Sputnik. In 1958, the U.S. deployed the first operational ICBM, the Atlas (14), followed closely by the Soviet Union which deployed SS-7, SS-8 and SS-9 missiles (15).

By 1970 both sides had roughly a thousand ICBMs. They had also successfully developed and deployed nuclear powered submarines capable of launching submarine launched ballistic missiles (SLBMs) from a position of secrecy and invulnerability underwater (16).

The next phase began in the early '70's - the introduction of multiple independently targetable re-entry vehicles (MIRVs). Previously, each ICBM or SLBM could only carry a single nuclear warhead (bomb). It now became possible for a single missile to disperse several warheads whilst still above the atmosphere, each warhead targeted on a separate location.

At present, both sides have enormous arsenals of nuclear weapons:

Strategic Nuclear Weapons in 1984

	USA	USSR
Long Range Bombers	241 (17)	143 (17)
Submarines	35 (17)	79 (17)
SLBMs	592 (17)	981 (17)
ICBMs	1,037 (17)	1,398 (17)
Total Warheads	9,665 (18)	8,880 (18)

As can be seen from the table, the USA has more bombers, and the Soviet Union has more submarines. The U.S.S.R. has more missiles but the U.S. has more warheads. The table does not show the smaller "battlefield" nuclear weapons of which the U.S. posseses over 5,000 and the U.S.S.R. over 1,000 (19).

In order to gain some perspective on the present balance, note that present nuclear warheads are typically around half a megaton, or about forty times more powerful than the Hiroshima bomb. The total power of these weapons is more than a thousand times the total of all the bombs used in World War II, leaving each side with the capability to destroy the other many times over. A recent study in *Science* of the effects of a

nuclear war between the two superpowers concluded that the explosion of as little as 100 megatons in surface bursts over cities could result in huge dust and smoke clouds encircling the earth causing a "nuclear winter" of subfreezing land temperatures for months (20). The "battlefield" weapons have yields of a few kilotons, and would have effects on populated areas comparable to the Hiroshima or Nagasaki bombs.

From the start of the arms race, it was realized by both sides that it was in no one's best interest for the arms race to continue indefinitely. The major arms control treaties which have been agreed on are listed below (21):

Arms Control Treaties

Antarctic Treaty 1959

Declares that the antarctic area is to be used only for peaceful purposes. In particular, nuclear explosions for any purpose are banned.

Limited Test Ban Treaty 1963

Prohibits nuclear testing or any other nuclear explosion in the atmosphere, in space, underwater, or in any other environment that would result in the appearance of radioactive debris outside the territory of the state responsible for the explosion.

Outer Space Treaty 1968

Prohibits the installation of nuclear weapons or any other weapons of mass destruction in earth orbit, on celestial bodies, or in outer space. Military installations, weapons testing, and the conducting of military manoeuvres on celestial bodies are all banned.

Non – Proliferation Treaty 1968

Prohibits nuclear weapons states from assisting in any way the aquisition of nuclear weapons by states which do not already have them. The parties commit themselves to negotiate treaties to end the arms race, achieve nuclear disarmament, and achieve general and complete disarmament.

Seabed Treaty 1971

Bans nuclear weapons from non-coastal waters.

SALT I (ABM Treaty) 1972

Prohibits deployment of anti-ballistic missiles except for the protection of two regions in each country. The nature of these ABM's is restricted. The protocol to this treaty (signed in 1974) limits the protected regions to one each.

SALT I Interim Agreement 1972

Freezes for five years the total number of ICBM and SLBM launchers.

SALT II 1979 - not yet ratified

Sets ceiling for both sides of 2,400 for total ICBM, SLBM, and long range air-to-surface ballistic missile launchers, and heavy bombers. Restricts MIRV'd missiles and throw-weight of launchers. Mobile ICBMs banned.

In spite of these efforts at arms control, the number and sophistication of nuclear weapons has continually increased. We are far from seeing the fulfillment of the pledges to provide a "discontinuation of all test explosions of nuclear weapons" and the "cessation of the nuclear arms race", pledges made by the signatories of the Non-Proliferation Treaty and the Limited Test Ban Treaty respectively. But there are only two ways out of the arms race: negotiation and agreement, or nuclear war.

III Military Programs in Industry and University

In February 1984, President Reagan announced his scientific research and development (R&D) budget for 1985. "Defense boom, physics boomlet" ran the headline in Physics Today (1), reflecting the 21% real increase in the Department of Defense (DoD) allocation. The DoD's $34 billion, together with the Department of Energy's $1.7 billion for nuclear weapons research, development and testing (2), brought the total for military research to nearly 65% of the whole federal R&D budget. If the budget is adopted by Congress, the military science budget will have doubled in real terms, in just four years (1).

Where does this money go to? Tactical nuclear and conventional programs get the biggest slice, $10.5 billion, closely followed by the strategic nuclear programs ($8.7 billion), including the Trident submarine launched missiles ($2 billion) and the MX missile ($1.7 billion) (2). The President's "Star Wars" program gets $1.8 billion, the first installment of $25 billion to be spent over the next five years.

What does a budget like this mean for you as a science, social science or engineering graduate, if you want to work in industrial or university R&D? How does the shift towards military research affect your employment prospects? What does it mean for industry and universities themselves?

In the U.S., nearly half of all R&D funding comes from the government (3), and as we mentioned above, two thirds of that goes to military work. Thus at least one third of all R&D effort goes into military projects. On that basis (4), we estimate that one in three, or about 200,000 of the 600,000 working scientists and engineers in the U.S. (5) work on military projects. Again estimating on the basis of money spent, at least a third of those, or almost 70,000, work on nuclear weapons projects. Other estimates put the number as high as 150,000 (6). The "Star Wars" program alone, on the basis of these estimates, will employ tens of thousands of new graduates over the next five

years. The Council on Economic Priorities in New York estimates that by 1986 nearly 30% of the growth of the total U.S. R&D effort will be related to that program, "making it a significant competitor with industry and other government projects for talent and resources" (14).

Eisenhower and the Military Industrial Complex

In 1946, immediately after World War II, General Eisenhower, Supreme Allied Commander, spoke warmly of the role of scientists:

"The armed forces could not have won the war alone. Scientists and businessmen contributed techniques and weapons which enabled us to outwit and overwhelm the enemy." (7)

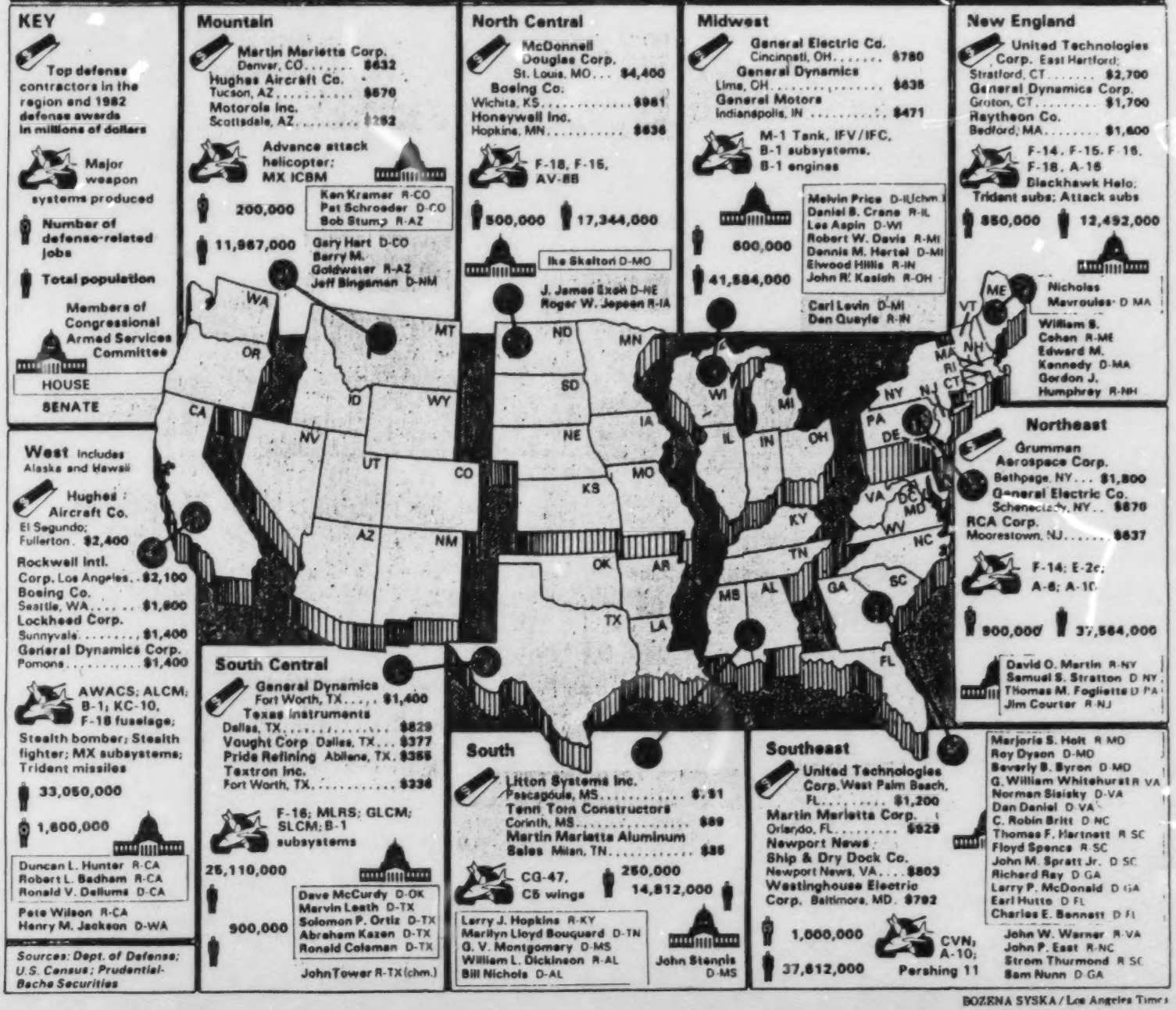
The successes of Los Alamos and other military laboratories led directly to a huge growth of military industry. Fifteen years later in 1961, after seven years as president, Eisenhower in his farewell address to the nation issued the following warning:

"Until the latest of our world conflicts, the United States had no armaments industry ... we have been compelled to create a permanent armaments industry of vast proportions. This conjuncture of an immense military establishment and a large arms industry is new in the American experience. The total influence - economic, political, even spiritual - is felt in every statehouse, every office of the federal government ... In the councils of government we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex." (8)

Of course, science R&D is only the tip of the iceberg as far as military- related employment goes. What Eisenhower called the "military-industrial complex" is now easily the largest employer in the U.S. (see map). The DoD's total budget for 1985 is $306 billion, or 29% of the total federal budget (2).

Most military R&D is done in industry, where it is concentrated in a small number of companies. The table overleaf shows the top six companies in military R&D (9) together with some of the nuclear weapons systems contracts they hold. These are the kind of projects you will be working on if you end up working on nuclear weapons.

The Geography of the Military-Industrial Complex



Source: Los Angeles Times, Sunday, July 10, 1983, Part VI, p.2.

BEST COPY AVAILABLE

Top Companies in Military R&D

Company	Nuclear-related contracts (prime=prime contractor)
Rockwell	B-1B bomber prime, airframe; Minuteman 2 guidance; MX flight computer and guidance.
Lockheed	Trident I RV prime, missile; Trident II prime; Ground and Sea Launched Cruise Missile targetting; Short Range Attack Missile for B-52; FB-111 propulsion; S-3 Viking prime; P-30 Orion prime.
McDonnell-Douglas	Ground, Sea and Air Launched Cruise Missile guidance; A4 Skyhawk prime, airframe; Eagle prime, airframe; F-18/A-18 Hornet prime, airframe; F-15 fighter; AV-8B Harrier II prime.
Boeing	Air Launched Cruise Missile prime; B-52 bomber prime; MX transporter, technical support for guidance & control.
General Dynamics	Ground Launched Cruise Missile prime, Tomahawk missile; Sea Launched Cruise Missile prime, airframe; FB-111 fighter prime; F-16 Fighting Falcon fighter; Trident I RV; Trident submarine.
United Technologies	Engine for Advanced Strategic Air Launched Cruise Missile; air cycle machine for Air Launched Cruise Missile.

Working in military industry has its benefits. The pay is usually better than in civilian industry. The projects are often more technologically advanced and better financed. However, military-related work carries with it a moral burden. Robert Aldridge worked as a design engineer for Polaris and Trident missiles:

> "I became a veteran engineer on sea based missiles and leader of an advanced design group. At the time I valued my work, but how it was evaluated troubled me: the Poseidon weapons system was given an "effectiveness rating" of 80 million fatalities."

As time went on, Aldridge became more and more worried by the development of accurate weapons and the possibility of their use in a first strike.

> "My children challenged my part in designing weapons. "Someone must have the courage to start" said my oldest daughter about abandoning that kind of work. Those words troubled me."

Finally, after 16 years at Lockheed, he left and wrote a book about the dangers posed by the weapons he worked on (10).

William Perry, Public Affairs Director at Lawrence Livermore Laboratory, where nuclear weapons are researched and designed, resigned in 1983 when he realized the implications of his work.

> "My kids began asking me about nuclear weapons and I was uncomfortable about the fact that I didn't have any answers. I did not know why I was working in a nuclear weapons factory...I gave my kids the standard answer that you hear at the laboratory. ..."We are involved in deterrence. Though there are some people who believe we ought to disband nuclear weapons, the only real way to achieve peace is to sit down at the table and negotiate from a position of strength." I could give that answer. I was very good at it. "

A conversation with the laboratory director, Edward Teller, started Perry thinking. Teller said that only 10% of the people would be killed in a limited nuclear war.

> "Then it hit me. 10% of the people that is twenty million lives. Any time you can write off twenty million lives that is amazing."(11)

Military research is not only done in industry or weapons laboratories. Much of the basic scientific research developing new techniques with military applications is done in universities. The agencies funding military research, the Departments of Defense and Energy, and NASA also support basic non-military research in universities and sometimes the distinction between military and non-military research is not clear. Below is a list of the top ten DoD-funded universities in 1983 (12):

Universities among the Top DoD Contractors in Fiscal 1983

Institution	DoD Research Grants in $ thousands		%Change	Ranking
	1979	1983		
Mass. Inst. of Tech.*	123,724	247,845	100.3	15
Johns Hopkins Univ.*	155,801	226,703	45.5	17
Illinois Inst. of Tech.	23,442	42,054	79.4	51
University of California	24,159	39,956	65.4	54
Stanford University	16,694	25,993	55.7	67
Georgia Inst. of Tech.	8,360	25,160	201.0	70
University of Texas	15,072	23,250	54.3	72
Penn. State University	14,560	20,436	40.4	77
University of Rochester	12,848	20,393	58.7	78
Univ. of Southern Calif.	-	18,762	-	81

*The big figures for MIT and Johns Hopkins represent mostly research at special defense laboratories managed by these schools (Lincoln Labs at MIT and the Applied Physics Lab at JH).

Probably the most important recent trend in military funding of university R&D is towards fifth generation computers. The DoD has allocated $600 million for its five-year Strategic Computing Program aimed at artificial intelligence (13). Funds to increase supercomputer experience particularly among young scientists have also been made available.

Other major basic research projects starting in 1985 include a major program under the Army for command, control and communications systems for air-land battles, and Air Force programs in image processing, high-speed microcircuits and spacecraft survivability, the latter very likely with "Star Wars" applications (1).

Working in a university with military funding is indeed very different from working in a nuclear weapons lab. However, in either case, you will undoubtedly face moral dilemmas. Should you work on projects which may have applications to nuclear weapons? Should you collaborate with others working on such projects? These and similar questions are bound to become more pressing over the next few years as the next stage of the arms race unfolds.

IV Future developments : From MX to "Star Wars"

On November 23, 1983, the Soviet Union walked out of the arms reduction talks at Geneva in protest over the deployment by NATO of Cruise and Pershing II missiles in England and West Germany (1). These missiles were deployed as a response to the SS-20 missiles introduced earlier by the Soviet Union. They are the first of a new generation of missiles, qualitatively different from previous ones, being accurate enough to destroy enemy missiles in their silos. A large variety of such weapons is planned, as we shall discuss below. In addition, under President Reagan's "Star Wars" program a range of entirely new weapons is planned.

In an atmosphere of worsening relations between the United States and the Soviet Union, the prospects for arms control treaties are not good. Some administration officials argue that past agreements have only served to put the U.S. at a disadvantage:

> "...some experts, including senior officials of the Reagan and previous administrations, are expressing profound doubts about the value and desirability of comprehensive new agreements on nuclear weapons."
>
> -Los Angeles Times, May 1983 (2)

New talks are however planned for 1985.

The arms control treaties now in force may soon be broken. The "Star Wars" weapons would violate the Outer Space Treaty and SALT I (the ABM Treaty), whilst the Small ICBM (the Midgetman—see below) would break SALT II. Until now, both sides have observed these treaties, even though SALT II was never formally ratified.

If you are employed in the nuclear weapons industry it is likely that you will work on one of the new weapons programs. Below is a list of some of the major programs underway in the U.S.. Needless to say the Soviet Union is also developing and deploying weapons in all of these categories.

Cruise missiles are small unmanned jet airplanes designed to carry a nuclear or conventional warhead. They fly about 100 feet above the ground at subsonic speeds, charting their course with the aid of radar and a map stored in a computer on board. They are designed to be accurate to within 30 meters after a 150 mile flight. They come in three types—**Ground Launched (GLCMs)** from mobile trucks, **Air Launched (ALCMs)** from B-52 bombers and **Sea Launched (SLCMs)** from ships and submarines. There are already 1500 ALCMs deployed and the first GLCMs arrived in Europe at the end of 1983. Present plans are for 4,348 ALCMs, 4,068 SLCMs, and 565 GLCMs to be deployed by 1987, 5000 with nuclear warheads. Each warhead has an explosive yield of 200 kilotons (kt). This is over sixteen times that of the Hiroshima bomb. The SLCMs are "dual capable," *i.e.*, they can carry either nuclear or conventional warheads. This makes the verification of numbers of nuclear SLCMs almost impossible. The total cost of these programs is set at $ 25 billion (3). In the longer term, 30,000 cruise missiles at a cost of $ 63 billion are planned, incorporating "stealth" technology which would make them invisible to radar (4). The Air Force is also planning a new program for a supersonic cruise missile—the **Advanced Strategic Air Launched Cruise Missile (ASALM)**. 1200 of these will be deployed starting in 1987 (5).

Pershing II missiles are truck-launched ballistic missiles, accurate over a 1000 mile flight to within 45 meters. They can therefore be used against Soviet missiles or command bunkers. They carry a 5 to 50 kt warhead, about the size of a Hiroshima bomb. Their short flight time—around 8 minutes—may force the Soviet Union to adopt a "launch on warning" policy out of fear of losing their own missiles (6). Present plans are for 108 missiles to be deployed in West Germany and the first of these have already arrived (7).

The MX missile is by far the most accurate ICBM yet built. Each one carries 10 to 12 independently targetable 300 kt warheads, accurate to within 150 meters. They

are to be targeted on hardened Soviet missile silos and command bunkers (7).

> "...With the MX deployed in substantial numbers, in addition to Minuteman, the U.S. would have acquired a capability to destroy most of the Soviet silo-based ICBM force in a first strike. Such a prospect could be of considerable concern to Soviet leaders since a significantly greater percentage of Soviet strategic weapons (about 75% for the U.S.S.R. *vs.* about 25% for the U.S.) is in its ICBM force, despite the fact that some [DELETED] percent of the Soviet's deployed strategic weapons could survive."(8)
>
> ...under extreme crisis conditions, the Soviet leaders, concerned that war was imminent, and fearing for the survivability of their ICBMs if the U.S. struck first, nonetheless might perceive pressures to strike first themselves. Such a situation, of course, would be unstable." (9)
>
> -President Jimmy Carter, 1980 and 1978.

Initial plans were for the MX to be deployed in one of a number of mobile basing modes, in order to be invulnerable to a surprise Soviet attack. However, after much controversy, present plans are for 100 MX missiles to be put in old Minuteman silos.

The Trident submarine-launched missiles are the most accurate yet deployed. Present plans are for 10 new submarines to be deployed by 1990, and 20 by 1998. There are 3 in service already, each with 24 Trident I missiles. These have 8 independently targetable 100 kt warheads, accurate to 450 meters and capable of destroying hardened targets. From 1988 on, the Trident II missile will replace them, with more warheads (9-15), greater explosive yield (150-600 kt), and greater accuracy (better than 150 meters). 480 missiles and 5000 warheads will eventually be deployed (11).

The Air Force is now planning a single-warhead ICBM, **Midgetman** or **"Small ICBM"**. Three or four thousand will be placed in well-separated shelters across the U.S. Alternatively, they may be based on mobile launchers. A modified version of Pershing II, **Pershing III**, with intercontinental range has also been reported (12).

In 1986, the Air Force will deploy 100 new intercontinental **B-1 Bombers**. With

a payload twice that of the B-52 bomber, it can carry ALCMs, **Short Range Attack Missiles (SRAMs)**, and nuclear bombs. The program cost is estimated to be between $30 and $40 billion (13).

The arms race on Earth is already well under way, but the arms race in space is only just beginning. On March 23, 1983, President Reagan launched the **"Star Wars"** program with the following appeal:

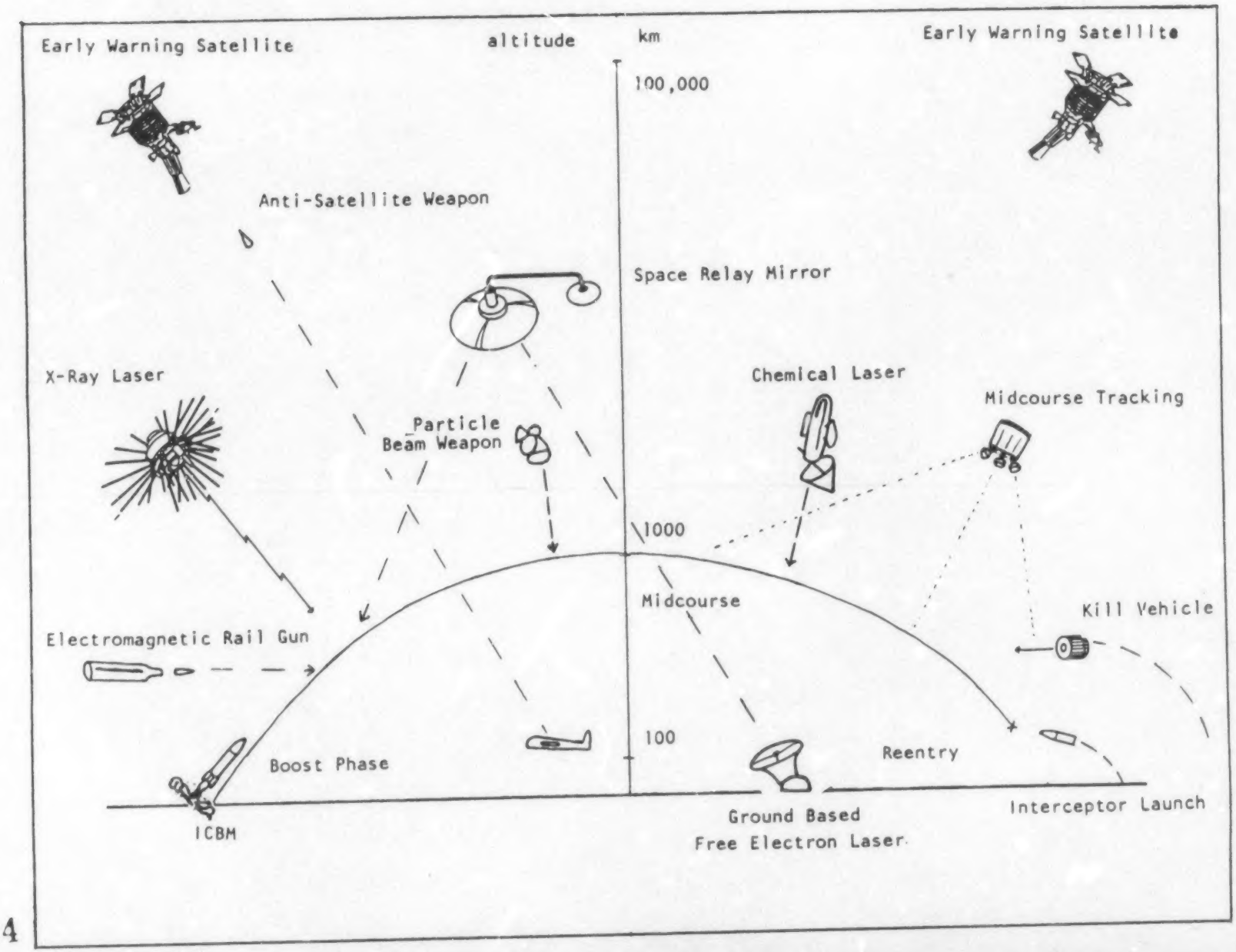
> "I call upon the scientific community who gave us nuclear weapons to turn their great talents to the cause of mankind and world peace: to give us the means of rendering these nuclear weapons impotent and obselete." (14)

The "Star Wars" plan is a program for new "defensive " weapons systems which can destroy incoming missiles in flight. It envisages the development of a huge array of **Anti-Ballistic Missile (ABM)** devices, based in space and on the ground, to "achieve our ultimate goal of eliminating the threat posed by strategic nuclear missiles" (15). The figure shows some of the proposed weapons—**chemical lasers, X-ray lasers, particle beam weapons**, and other **non-nuclear projectiles ("kill vehicles")** and **orbiting mirrors** deflecting beams from **ground-based lasers** (16). Over the next five years, the Defense Department is to spend around $25 billion on developing them. The first $1.8 billion is to be spent this year. This amount alone is greater than the entire budget of the National Science Foundation for basic research in all sciences (17).

There are enormous technical problems with the "Star Wars" plan, and many experts doubt whether the scheme will work (18). A recent U.S. Congress Office of Technological Assessment report says the chances of the project's succeeding are "remote" (19). The "Star Wars" plan would also be totally ineffective against submarine launched missiles or cruise missiles.

The Star Wars plan is also dangerously destabilising. The Soviets in particular may regard it as an attempt by the U.S. to build a first strike capability - a capability to destroy Soviet missiles while not itself being threatened. The Soviets have already

The "Star Wars" Weapons



said they would introduce countermeasures such as space mines if the U.S. deploys any of the new weapons (20). The decades it will take to develop the system will give the Soviet Union ample time to build up their own "Star Wars" weapons. The main effect of the "Star Wars" program may therefore simply be to open a new arena for the arms race.

It is not only through the "Star Wars" program that space may become the battlefield in a future nuclear war. **Anti-satellite weapons (ASATs)** are targeted against satellites used for communications, reconnaissance and early warning systems. The U.S. tests of the original ASAT systems were discontinued in 1975 as being ineffective and in 1982 the Soviets announced a moratorium on ASAT testing, submitting an ASAT arms control proposal to the United Nations (21). However, the U.S. is developing a new ASAT system, which was successfully tested in January 1984 (21). The new system is a small rocket fired into space from an F15 fighter plane at high altitude. This weapon is capable of threatening Soviet early warning satellites.

Conclusion

It should be clear from the above that the next few years will see a boom in recruitment of scientists and engineers for the new weapons systems. As a new graduate you will face the decision of whether or not to work on one of them. By working on them you will be actively contributing to the next phase of the arms race. Even if you decide not to, you may still be involved in it. Whatever your decision, as a scientist or engineer you have a special responsibility to keep yourself informed and to help educate others on these important issues.

References

Chapter I

(1) Quoted in Herbert York, *The Advisors: Oppenheimer, Teller and the Superbomb*, W.H. Freeman and Co., San Francisco, 1976, p.71.

(2) *Los Angeles Times*, July 10, 1983, Part VI, p.6.

(3) Solly Zuckerman, *Nuclear Illusion and Reality*, Random House, New York, 1983, p.105.

Chapter II

(1) Quoted in A.C.Brown and C.B.MacDonald, *The Secret History of the Atomic Bomb*, The Dial Press, New York, 1977, p.xi.

(2) ibid p.532.

(3) Committee for the Compilation of Materials on Damage Caused by the Atomic Bombings at Hiroshima and Nagasaki, *Hiroshima and Nagasaki: the Physical, Medical and Social Effects of the Atomic Bombings*, trans. E.Ishikawa and D.L.Swain, Hutchison, London, 1981.

(4) T.Akizuki, *Nagasaki 1945*, Quartet, London, 1981, pp.118,122.

(5) H.York, *The Advisors: Oppenheimer, Teller and the Superbomb*, W.H. Freeman and Co., San Francisco, 1976, p.71.

(6) Quoted by H.York and A.Greb, *Scientists as Advisors to Governments*, in J.Rotblat (ed.), *Scientists, the Arms Race, and Disarmament*, Taylor and Francis, London, 1982, p.86.

(7) T.Akizuki, *Nagasaki 1945*, Quartet 1981, p.65.

(8) ibid p.82.

(9) ibid p.89.

(10) R.P.Berman and J.C.Baker, *Soviet Strategic Forces: Requirements and Responses*, Brookings Institution, Washington D.C., 1982, p.43.

(11) ibid pp.136,138.

(12) ibid p.49.

(13) T.B.Cochran, W.M.Arkin and M.M.Hoenig, *Nuclear Weapons Databook: Volume I, U.S. Nuclear Forces and Capabilities*, Ballinger, Cambridge MA, 1984, p.11.

(14) ibid p.12.

(15) R.P.Berman and J.C.Baker, *Soviet Strategic Forces: Requirements and Responses*, Brookings Institution, Washington D.C., 1982, p.49.

(16) ibid p.42.

(17) International Institute for Strategic Studies, *The Military Balance 1984-1985* , IISS, London, 1984, pp.4, 17.

(18) Stockholm International Peace Research Institute, *The Arms Race and Arms Control 1984* , SIPRI, Stockholm, 1984, pp.22, 25.

(19) R.Forsberg, *A Bilateral Nuclear Weapons Freeze*, Scientific American, Nov.1982, p.5.

(20) R.P.Turco, O.B.Toon, T.P.Ackerman, J.B.Pollack and C.Sagan, *Nuclear Winter: Global Consequences of Multiple Nuclear Explosions*, Science, 23 Dec.1983, p.1283.

(21) United States Arms Control and Disarmament Agency, *Arms Control and Disarmament Agreements*, USACDA, Washington D.C., 1982.

Chapter III

(1) *Physics Today*, April 1984, p.55.

(2) *Aviation Week and Space Technology*, February 6, 1984, p.14

(3) *Science Resources Studies Highlights*, National Science Foundation, Washington D.C., October 14 1983, p.2.

(4) It is difficult to obtain figures for the number of scientists employed on military projects. Estimating on the basis of cost overestimates because military R&D is relatively cost intensive, but we also underestimate by ignoring other funding sources for R&D.

(5) *Science Indicators 1978*, Report of the National Science Board, Washington D.C., 1979, p.224.

(6) R.Forsberg, *The Economic and Social Costs of the Nuclear Arms Race*, Institute for Defense and Disarmament Studies, Occasional Paper 2, March 1981, p.5.

(7) Quoted in S.Melman, *Pentagon Capitalism*, New York, 1970, p.232.

(8) *Public Papers of the Presidents of the United States, Dwight D. Eisenhower 1960-61*, Washington D.C., 1981. Farewell radio and television address to the American people, January 17 1961, p.421.

(9) G.Adams, *The Iron Triangle : the Politics of Defense Contracting*, New York, 1981, p.97.

(10) R.C.Aldridge, *First Strike : The Pentagon's Strategy for Nuclear War*, South End Press, Boston MA, 1984, p.14.

(11) *The Graduate Theological Union*, Berkeley, November 1983.

(12) S.Burkholder, *The Pentagon in the Ivory Tower*, The Progressive, June 1981, p.25. (1979 figures); Fact-File (1983), U.S. Dept. of Defense source.

(13) *Chronicle of Higher Education*, March 14, 1984.

(14) *Chronicle of Higher Education*, November 14, 1984 , p.6.

Chapter IV

(1) *Los Angeles Times*, November 24, 1983.

(2) *Los Angeles Times*, May 27, 1984.

(3) T.B.Cochran, W.M.Arkin and M.M.Hoenig, *Nuclear Weapons Databook: Volume I, U.S. Nuclear Forces and Capabilities*, Ballinger, Cambridge MA, 1984, p.172.

(4) *Aviation Week and Space Technology*, August 23, 1982.

(5) T.B.Cochran, W.M.Arkin and M.M.Hoenig, *Nuclear Weapons Databook: Volume I, U.S. Nuclear Forces and Capabilities*, Ballinger, Cambridge MA, 1984, p.195.

(6) J.Steinbruner, *Launch Under Attack*, Scientific American, January 1984, p.37.

(7) T.B.Cochran, W.M.Arkin and M.M.Hoenig, *Nuclear Weapons Databook: Volume I, U.S. Nuclear Forces and Capabilities*, Ballinger, Cambridge MA, 1984, p.295, 121.

(8) *Fiscal Year 1981 Arms Control Impact Statements* , May 1980, p.65.

(9) *Fiscal Year 1979 Arms Control Impact Statements* , June 1978, p.21.

(10) *Los Angeles Times*, May 24, 1984.

(11) T.B.Cochran, W.M.Arkin and M.M.Hoenig, *Nuclear Weapons Databook: Volume I, U.S. Nuclear Forces and Capabilities*, Ballinger, Cambridge MA, 1984, p.138.

(12) ibid. p.132.

(13) ibid. p.159.

(14) *Los Angeles Times*, March 24, 1984.

(15) ibid.

(16) *Aviation Week and Space Technology*, October 17, 1983, p.17.

(17) *Physics Today*, April 1984, p.55.

(18) Union of Concerned Scientists, *Space Based Missile Defense*, U.C.S. Report, Cambridge MA, March 1984.

(19) *Report by Office of Technology Assessment*, U.S. Congress, May 1984.

(20) *Los Angeles Times*, May 14, 1984.

(21) R.L.Garwin, K.Gottfried and D.L.Hafner, *Antisatellite Weapons*, Scientific American, June 1984, p.45.

Suggested Reading List

(a) Reference Works

The Effects of Nuclear Weapons by S.Glasstone and P.J.Dolan (eds.), Departments of Defense and Energy, 1977.
The most authoritative book on the subject.

Nuclear Weapons Databook: Volume I, U.S. Nuclear Forces and Capabilities by T.B.Cochran, W.M.Arkin and M.M.Hoenig, Ballinger, Cambridge MA, 1984.
By far the most comprehensive book on weapons characteristics. Also contains short sections on the history of the U.S. stockpile and on how nuclear weapons work.

Soviet Strategic Forces : Requirements and Responses by R.P.Berman and J.C.Baker, Brookings Institution, Washington D.C., 1982.
The most detailed book on Soviet forces. Includes historical material and discusses Soviet strategy at length.

The Military Balance produced and published annually by the Institute of Strategic Studies, London.

The SIPRI Yearbook of World Armaments and Disarmament produced annually by the Stockholm International Peace Research Institute, published by Taylor and Francis, London.

Arms Control and Disarmament Agreements produced and published by the U.S. Arms Control and Disarmament Agency, Washington D.C., 1982.
Contains full texts and historical accounts of all treaties so far.

(b) A General Introduction

Nuclear War : What's in it for you ? produced by Ground Zero, published by Simon and Schuster, New York, 1982.

(c) On Military Industry

The Iron Triangle: the Politics of Defense Contracting by G.Adams, New York, 1981.

Servants or Masters ? Revisiting the Military-Industrial Complex , a special report for the Los Angeles Times, July 10 1983, Part VI.

(d) On The Recent Developments

First Strike : the Pentagon's Strategy for Nuclear War by R.C.Aldridge, South End Press, Boston Ma, 1983.
A former design engineer for Polaris and Trident missiles, Aldridge provides a very readable account of U.S. nuclear strategies and capabilities, and a clear warning about the future.

With Enough Shovels : Reagan, Bush and Nuclear War by Robert Scheer, Random House, New York, 1982.
"It is an astonishing book and a superb job of reporting" - Jerome Wiesner, President of MIT.

(e) Star Wars And ASATS

The New High Ground by T. Karas, Simon and Schuster. New York, 1983
Historical overview of the weapons, the economics and the personalities shaping the military-space policies of the future.

Antisatellites (Killer Satellites) by M.S. Smith, Issue Brief #IB81123, Congressional Research Service, 8/22/1983.

Space Policy and Funding: Military Uses of Space , Issue Brief #IB82117, Congressional Research Service, 12/29/1983.

American Military Space Policy: Information Systems, Weapons Systems and Arms Control by C.S. Gray, Abt Books, Cambridge, MA 1982.
A concise review of satellite systems, ASATs, ABMs and problems and prospects of arm control.

Space-Based Missile Defense , a report by the Union of Concerned Scientists, March 1984.

(f) Periodicals

Bulletin of the Atomic Scientists
Articles on nuclear war and arms control.

Aviation Week and Space Technology
Trade journal on new weapons systems.

Appendix: Non – Military Jobs

It is not always easy for science and engineering graduates to find non-military employment, outside of the universities. In this appendix we list a few organisations which may be able to help you.

We know of three organizations which are compiling databases of industrial companies and their military contracts:

- High Technology Professionals for Peace (HTPfP)
  639 Massachusetts Ave., Room 316
  Cambridge, Massachusetts 02139
  (617) 497-0605

  The database of HTPfP at present contains all Massachusetts companies. It lists which firms are willing to employ scientists and engineers who refuse to work on military projects.

- National Action-Research on the Military Industrial Complex (NARMIC)
  AFSC-NARMIC, 1501 Cherry St.
  Philadelphia, Pennsylvania 19102
  (215) 241-7175

  Publishes a variety of fact sheets, slide shows and films about the U.S. defense establishment. NARMIC can provide information on DoD awards by company or county.

- Box WN
  Department of Physics, University of California
  Berkeley, California 94720

  A group of physicists providing statistics on how much of the scientist/engineer job market is military related.

Some of the organizations working towards economic conversion of companies away from defense-related work are:

- Center for Economic Conversion
  222c View St.
  Mountain View, California 94041
  (415) 968-8798

  Publishes *Plowshare*, a bimonthly paper on conversion-related issues. Issues reports on conversion projects and on non-military jobs.

- Bay State Center for Economic Conversion
  639 Massachusetts Ave., Room 316
  Cambridge, Massachusetts 02139
  (617) 497-0605

- Employment Research Associates
  474 Hollister Building
  Lansing, Michigan 48933
  (517) 485-7655

Other organizations and groups of scientists and technical professionals concerned with the arms race and economic conversion are:

- Aerospace Engineers/Workers for Social Responsibility
  P.O. Box 21471, Los Angeles, California 90021
- Computer Professionals for Social Responsibility
  P.O. Box 717, Palo Alto, California 94301
- Federation of American Scientists
  Nuclear War Education Project
  307 Massachusetts Ave. N.E.
  Washington, D.C. 20002
- Union of Concerned Scientists
  26 Church Str.
  Cambridge, Massachusetts 02138